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Measurements of Attenuation and Talk-through Amplification for Two Communications Headset Candidates for the Helmet Electronics and Display System-Upgradeable Protection (HEaDS-UP) Army Technology Objective (ATO)

by Angelique A. Scharine and Mary S. Binseel

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Aberdeen Proving Ground, MD 21005

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14. ABSTRACT
Two tactical communication and protection systems (TCAPS) prototypes were developed for the Helmet Electronics and Display System-Upgradeable Protection (HEaDS-UP) Army Technology Objective (ATO). Attenuation measurements were made for the candidate systems in each of three configurations: in-the-ear (ITE), circumaural, and both (double). Features in the data obtained with the KEMAR auditory test fixture led to additional measurement using a G.R.A.S. hearing protector test fixture type 45CA, but neither set of measurements showed significant differences between the two candidates; in the second set of measurements, two Combat Vehicle Crewmember (CVC) headset variants were included for comparison purposes. The ITE configuration of the candidate systems compared well with that of the CVC in terms of attenuation and reliability. Measurements were also made of the noise levels transmitted by the talk-through microphones. The levels of sound measured for steady-state noise were well above 85 dB A-wtd, suggesting that the trigger mechanism for transmission shut-off is not triggered by steady-state noise and that users need to be trained to shut off the talk-through when exposed to vehicle and other steady-state noise for longer periods of time.

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Executive Summary

The Helmet Electronics and Display System-Upgradeable Protection (HEaDS-UP) Army Technology Objective (ATO) is developing conceptual, integrated, head-borne systems. These systems are comprised of ballistic, chemical, and biological protection; helmet-mounted displays and other equipment; and tactical communication and protection systems (TCAPS). In this effort, two sets of attenuation measurements were made for two candidate TCAPS—the first provided by Television Equipment Associates (TEA) and the second by SELEX Communications (SELEX), both of which consist of an in-the-ear (ITE) component and a circumaural component. The components can be worn individually or together. Radio communications capability is included in both components. Two Combat Vehicle Crewmember (CVC) headset variants were included in the second set of attenuation measurements for comparison purposes. Both the ITE and circumaural components also feature talk-through and amplification functions for passing through ambient sounds. Measurement was made of the sound levels of noise at the eardrum passed through by the talk-through microphones.

The resulting measurements are intended for comparison purposes only and do not necessarily reflect values that would be achieved using human subjects. The results show no significant differences in the amount of hearing protection provided by the candidate headsets. Both headsets offer protection consistent with that advertised by the manufacturer and the variability of protection is attributable to differences in fitting. The CVC headsets represent the optimum level of protection; however, the protection provided by the ITE configuration of the candidate systems was only marginally less than that of the CVC.

Sound pass-through measures were made of the noise levels under the circumaural headsets when the talk-through features were turned on. The maximum sound level measured under the circumaural headsets with the talk-through feature engaged was about 115 dB A-wtd when the noise presented was 133 dB A-wtd. This suggests that there was about 18–20 dB A-wtd of passive attenuation, and that the headset was not transmitting through the talk-through channel when the noise was at that level. However, the talk-through system presented even low level sounds (about 78 dB A-wtd) at about 95–100 dB A-wtd, suggesting that some amplification was occurring. This might be surprising given that similar systems advertise a maximum pass-through level of about 82 dB. It is surmised that the headsets are designed to transmit and even amplify speech and other lower-level ambient noises in order to enhance auditory situation awareness. While the shut-off mechanisms are designed to prevent transmission of abrupt impulsive noise, such as weapon-fire, the electronic shut-off is most likely triggered by the slope of the rise time, and not by the overall level. As a result, the steady-state noise used in this study did not trigger the shut-off circuit. This highlights the need for users of these devices to be instructed in their use and informed that the hearing protection features will not function if the

talk-through feature is turned on in the presence of steady-state noises. Given that the ability to hear and comprehend speech is highly desirable, and unlikely to reach a time weighted average of 85 dB over an 8-h period even if it is presented at instantaneous levels that are at 100 dB, these levels are probably appropriate if the headsets are used properly.

1. Introduction and Background

The Helmet Electronics and Display System-Upgradeable Protection (HEaDS-UP) Army Technology Objective (ATO) is developing conceptual integrated head-borne systems. These systems are comprised of ballistic, chemical, and biological protection; helmet-mounted displays and other equipment; and tactical communication and protection systems (TCAPS). The U.S. Army Research Laboratory's (ARL) Human Research and Engineering Directorate (HRED) conducted measurement of the insertion loss (attenuation) created by these TCAPS headsets in order to aid in evaluation of the headsets. Like many of the newer communications headsets used for military applications, the candidate headsets under test have talk-through microphones to restore ambient sound. A volume control button allows the user to set the amplification of the ambient sound to the user's desired level. For information purposes, measurements were also made with the talk-through function enabled to measure the actual sound levels being passed to the listener.

The measurements here do not replace the Noise Reduction Rating* (NRR) published by the manufacturers. The NRR is defined by Environmental Protection Agency (EPA) Title 40 CFR Subpart B (1979). This regulation has been revised and is under review, as it was based on ANSI S3.19 (1974), which has since been withdrawn. The proposed EPA regulation advises that hearing protection manufacturers compute the NRR from Real-ear Attenuation at Threshold (REAT) measurements as specified in American National Standards Institute/Acoustical Society of America (ANSI/ASA) S12.6 Method A. These calculations require measuring the hearing thresholds for narrow bands of noise presented to trained listeners both with and without the hearing protector in place. The main advantage of the REAT is that it gives the real human performance of a hearing protective device (HPD) for a group of listeners. It requires that ANSI/ASA S12.68 (2007) be used to compute the NRR. ANSI/ASA S12.68 prescribes the computation of the reduction in exposure for a group of listeners for a range of different noise spectra. Then, a range of reduction values based on the distribution of measured values is calculated. Thus, the NRR would be reported as a range, such as the 20th and 80th percentile of attenuation measurements. Generally the noise spectra used are the National Institute for Occupational Safety and Health (NIOSH) 100 spectra (Johnson and Nixon, 1974).

However, testing a group of listeners is time consuming and costly, and because the attenuation performance is initially unknown (it's what we're determining with the measurements), it is not possible to safely test human listeners in the levels of noise for which HPDs are commonly used. The objective of these measurements was to obtain data for comparison purposes. ANSI/ASA

* NRR is a calculated value based on the attenuation achieved at the audiometric frequencies of 125, 250, 500, 1000, 2000, 4000, and 8000 Hz using human subjects.

S12.42 specifies a method for the measurement of HPDs using an auditory test fixture[†] (ATF). This method is an adaptation of the Microphone in Real Ear (MIRE) test and allows the measurement of attenuation of hearing protectors against both steady-state and impulsive noise. The MIRE is less time intensive, but cannot predict intersubject variability. Its main advantage is that it can show the response to levels of noise that could be considered dangerous to human listeners. We used the ATF methodology described in ANSI/ASA S12.42, first with a Knowles Electronic Manikin for Acoustic Research (KEMAR) manikin-style ATF and then with a G.R.A.S. 45CA ATF.

The two candidate headset systems evaluated in this study are shown in figure 1. The Television Equipment Associates (TEA) system consisted of an Mine Safety Appliances (MSA) Sordin Supreme circumaural headset, an MSA Invisio in-the-ear (ITE) headset, and a TEA X50 Digital push-to-talk (PTT) control box[‡] with a special headset integration cable that allowed both the earmuffs and the headset to be connected to the TEA X50 control box. The SELEX Communications (SELEX) system consisted of a SELEX circumaural headset, ITE headset and a CTX Tactical Control Unit.

Figure 1. Headsets under evaluation. The TEA system includes an MSA Sordin Supreme circumaural headset, MSA Invisio ITE headset, a TEA X50 Digital PTT control box and a headset integration cable. The SELEX system is comprised of a circumaural headset, ITE headset, and a CTX tactical control unit.

[†] An acoustic test fixture is a manikin or similar device with microphones inside the ears, which allow the measurement of sound levels at the eardrum location.

[‡] The PTT and the control boxes on these systems are often referred to as PTTs; however, these components control the level of the ambient noise pass through channel as well as connections to three different types of radios. The SELEX system provided a separate cordless PTT; therefore, we avoided using the term PTT for the control box.

Both candidates had the following elements: circumaural communications earmuffs, an ITE communications headset, and a control box that allowed the headsets (circumaural and ITE) to function independently or jointly. This allows the user a choice in delivery of hearing protection and communications, as well as the option for dual hearing protection, all of which interface with radio communications. For both candidates, the ITE component was used with Comply™ foam tips. Both systems provide talk-through microphones that allow the user to hear ambient sounds through an externally placed microphone, regardless of whether single (circumaural or ITE) or dual (both) hearing protection is worn. Both systems allow the user to control amplification of the ambient noise via the control box when talk-through is enabled. Both control boxes connect to up to two radios and both come with cables that allow connection to the Rifleman Radio, the Enhanced Position Location Reporting System (EPLRS), and the Wearable Soldier Radio Terminal (WSRT) Radio.

The TEA X50 digital control box required an extra headset integration cable for use in the dual protection mode. The buttons on the MSA Sordin Supreme headset were disabled and all adjustments and control were accessed through the X50 control box. When the X50 control box buttons are pressed, a voice prompt indicates the setting: “ambient [talk-through] on,” “radio on,” etc.

The SELEX CTX control box has cable extensions that allow connection to up to two radios and an intercom, thus allowing space on the control box for the connection of both headsets. When the circumaural headset is used alone, ambient levels can be controlled via buttons on the headset; otherwise, control is via the control box.

2. Test Methods

Measurements were made of the passive attenuation hearing protection (insertion loss) offered by the two headsets and the gain provided by their talk-through features. It should be cautioned that the measurements of insertion loss used here were meant to allow comparison between the two headset candidates.

2.1 Auditory Test Fixtures

Two auditory test fixtures (figure 2) were used to make insertion loss measurements. First, measurements were made with a G.R.A.S. KEMAR manikin. This fixture was developed for use in the recording and measurement of hearing aid effects on the sound signal. It is also used frequently for making binaural recordings because the stereo signal recorded from it includes the binaural difference cues and monaural spectral cues that give spatial context. It is not ideal for evaluating hearing protectors. Berger (1992) compared results from measurements made with a KEMAR with those of other devices and showed that reasonable results were obtained for devices with an intentional auditory pathway. When the pathway is closed, as is the case of

passive attenuation measurements, there is a potential for resonance, particularly at higher noise levels. To avoid this problem, lower levels of noise were presented.

Figure 2. Auditory test fixtures used for measurement of the candidate systems: (left) KEMAR acoustic manikin[§] and (right) G.R.A.S. Hearing Protector Test Fixture Type 45CA (shown with TEA circumaural headset).

In mid-project, an acoustic test fixture (G.R.A.S. 45CA), which meets the IEC 60711 specification for the measurement of insertion loss of earmuffs, became available (G.R.A.S., 2011). For confirmation of the KEMAR data, selected measurements were repeated using the new fixture; both data sets are reported here.

Microphones in both test fixtures used were calibrated with a G.R.A.S. Type 42AA piston-phone calibrator prior to data collection. Data were collected using Etymotic Research ER-11 microphones mounted in the KEMAR or G.R.A.S. 40AG microphones mounted in an RA0045 IEC 60711 coupler in the 45CA, a 01-dB Symphonie data collection card, and 01-dB software installed on a Dell laptop.

2.2 Test Facility and Sound Sources

Testing was conducted in the Dome Room of the Environment for Auditory Research, an ARL facility at Aberdeen Proving Ground, MD (see Henry, Amrein and Ericson, 2009). This room meets the criteria for an anechoic chamber. Four large JBL PRX512M loudspeakers were used

[§] Currently, G.R.A.S. distributes the KEMAR manikin; however, this one was purchased from Etymotic.

to present white noise (as required by ANSI S12.42) at a level of 85 dB A-wtd[**], measured with a Quest™ 1200 sound level meter[††].

2.3 Number of Measurements

Consistent with ANSI S12.42 (American National Standard Methods for the Measurement of Insertion Loss of Hearing Protection Devices in Continuous or Impulsive Noise Using Microphone-in-Real-Ear or Acoustic Test Fixture Procedures), the Natick Soldier Research, Development & Engineering Center (NSRDEC) HEaDS-UP program provided five headset exemplars of both the SELEX and TEA systems. This allowed us to measure variability across the exemplars of each system. Three configurations were measured:

- ITE only;
- circumaural only; and
- double protection.

Two measurements per trial were made, one per ear. Two trials were performed, with removal and replacement of the system between measurements (to assess the variability due to fitting). Therefore, for each system configuration there were 20 measurements (5 exemplars x 2 ears x 2 trials) or 60 measurements for each system total (20 measurements per configuration x 3 configurations).

3. Results

The average attenuation values are shown in figure 3 and attenuation as a function of frequency is shown in figure 4. All error bars shown are standard error of measurement[‡‡].

[**] This level was selected for two reasons: (1) it is the limit for an unprotected daily noise exposure (AR 40-5) and (2) due to limitations of the acoustic manikin used (KEMAR), there was a risk of resonance of the hollow chambers in the manikin if the noise was presented at higher levels.

[††] A RadioShack digital (33-2055) sound level meter was used to check the level after initial calibration.

[‡‡] Standard Error is usually smaller than standard deviation—a good rule of thumb is that if the length of the error bars can be doubled and still not overlap, there is a significant difference. This is not the case here.

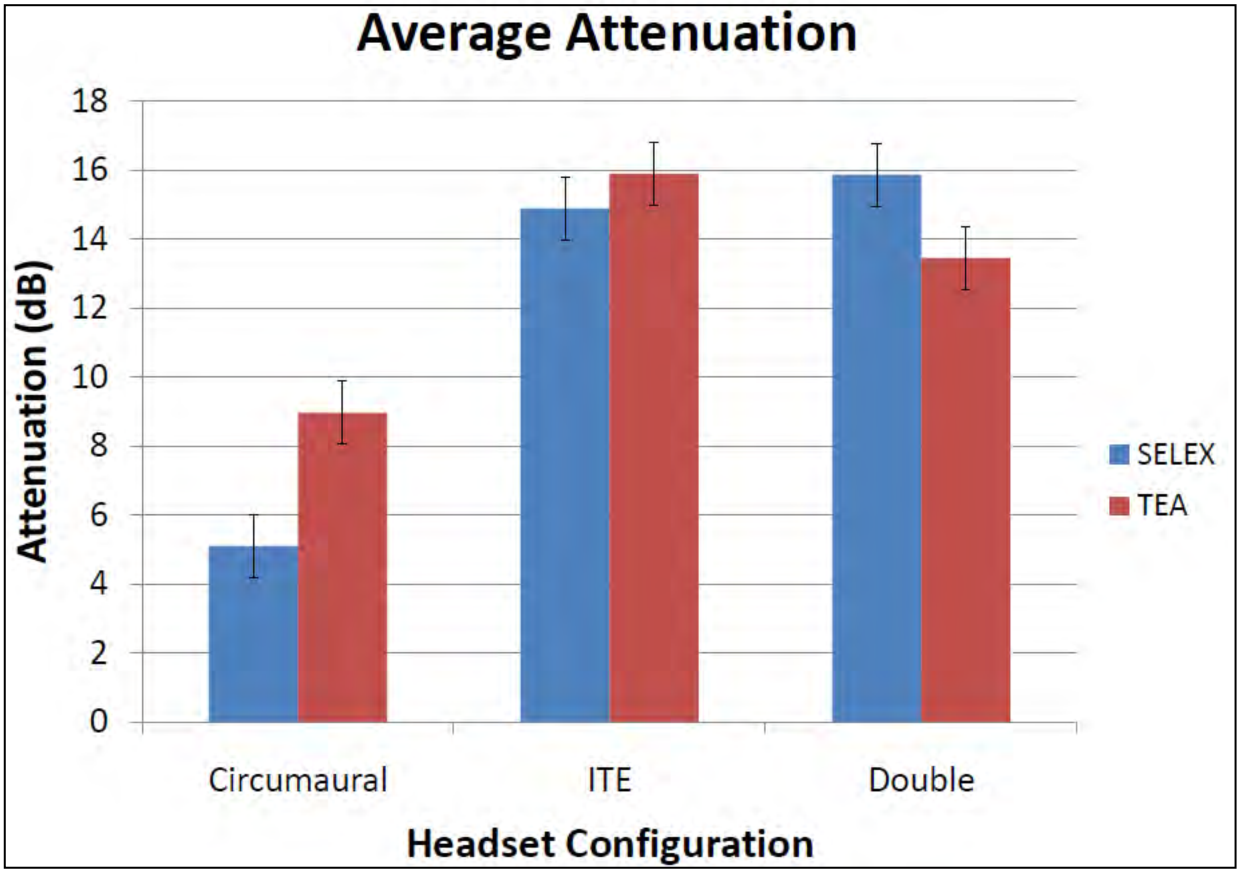

Figure 3. Average overall attenuation provided by the headsets under test in each of the three test configurations. Error bars show standard error.

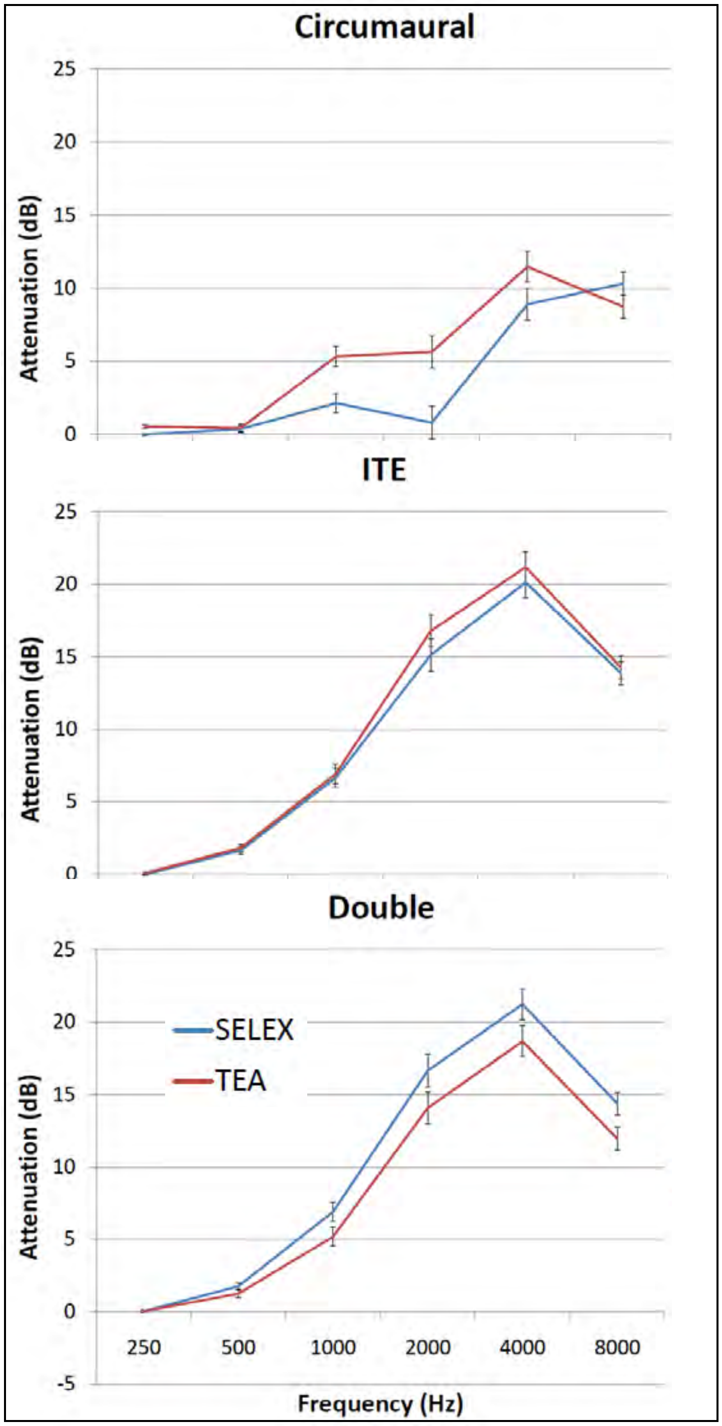

Figure 4. Attenuation provided by the systems in each of the three test configurations; measured for each octave band from 250 to 8000 Hz.

In–the-ear

There were no statistically significant differences between the headsets in the ITE configuration. This was predicted because they both use the same Comply™ foam inserts to provide passive

attenuation. The minor differences in the data are probably due to variability of fitting or differences in wire management. The TEA configuration requires that its "bone microphone[§§]" be seated inside and against the tragus and a "flexible spring" tucked up inside the concha against the antihelix, making it more difficult to insert, but making the results more repeatable as evidenced by the TEA-ITE measurements having a standard deviation of 0.4 dB versus 3.1 dB for the SELEX-ITE.

Double Hearing Protection

Double protection can provide 5–10 dB of additional attenuation (Berger, 1983). However, this figure can be much less, because the combination of circumaural earmuffs with an earplug can interfere with the fit of the earplug and/or disrupt the seal of the earmuffs (Abel and Odell, 2006). This probably occurred in our measurements; the double configuration did not provide much additional attenuation—at least as measured by the KEMAR. In the case of the TEA system, there was, on average, 2 dB less attenuation than what was measured for the ITE and the standard deviation was 7.5 dB. Conversely, double protection increased the attenuation of the SELEX system by 1 dB and decreased the standard deviation to .4 dB. It is likely that the TEA circumaural earmuffs disrupted the ITE earpiece and the wires add leakage to the seal of the earmuffs.

The attenuation measured on the KEMAR with double hearing protection was less than the minimal 3–5 dB found by Abel and Odell (2006). This may be explained by the fact that the contact surface of the KEMAR manikin is hard and the circumaural headsets did not appear to be making a good seal. Consistent with previous findings, the attenuation of circumaural headsets is less than that of ITE headsets. However, the amount of attenuation is somewhat less than what might be expected from NRR ratings. Our lower results may be due to the fact that the KEMAR has a hollow interior and, as such, can become a resonant chamber. To avoid resonance, the noise level used was significantly below that recommended by S12.42. However, this may not have been sufficient to prevent some leakage due to internal resonance.

To confirm measurements, a G.R.A.S. Hearing-Protector Test Fixture Type 45CA was obtained and a second set of measurements was made on a random subset[***] of two headsets. As before, each headset was fitted on the test fixture twice, thus providing us with four data points for each headset and condition. Therefore, for each system configuration there were 8 measurements (2 exemplars x 2 ears x 2 trials) or 24 measurements for each system total (8 measurements per configuration x 3 configurations). While the first set of measurements is useful for determining variability of performance, this second set of measurements gives a more accurate estimate of performance in high levels of noise. Additionally, as requested by the HEaDS-UP program manager, measurements were made of two Combat Vehicle Crewman (CVC) headsets: a Bose®

[§§] This is more correctly a tissue microphone, as it primarily makes contact with the cartilage of the pinnae. The functionality of the microphone has not been evaluated here.

[***] Since performance was more or less equivalent on all of the headsets, two exemplars were picked at random.

Product Improved CVC (PICVC) headset and a Sonetronics CVC headset. Figure 5 shows the three headsets as mounted on the test fixture. Measurements were made for two fittings of each CVC, thus providing us with four data points per headset and 12 data points overall.

Figure 5. G.R.A.S. Hearing-Protector Test Fixture Type 45CA shown with each of the headsets under test and a CVC. Left to right are the SELEX system, the TEA system, and the Bose PICVC (the Sonetronics CVC is not pictured here).

Figures 6 and 7 show the results of the measurements taken with the G.R.A.S. 45CA fixture. There appeared to be a better seal of the circumaural earmuffs against the flat surface of the test fixture and this fact is evidenced by an overall improvement in the headset measurements reported here. The greatest increases in measured attenuation were seen in the passive attenuation provided by the circumaural headsets. As found before, there were no significant differences between the average attenuation provided by the TEA and SELEX headsets. The amount of attenuation measured for the ITE condition was slightly less than that measured for the CVC headsets; however, the TEA and SELEX headsets are intended for use in the dismounted context, which has different requirements for mobility and situational awareness than CVC headsets, which are used in higher-noise mounted applications. The wearing of double protection did not provide significantly greater attenuation over that of the ITE condition alone; however, it decreased the attenuation variability. The standard deviation of the measurements in the ITE configuration were 1.8 (SELEX) and 0.5 (TEA) dB. The standard deviation of the measurements of the double configuration was 0.5 for both systems under test. In comparison, the standard deviation of the CVC measurements was 1.6 dB.

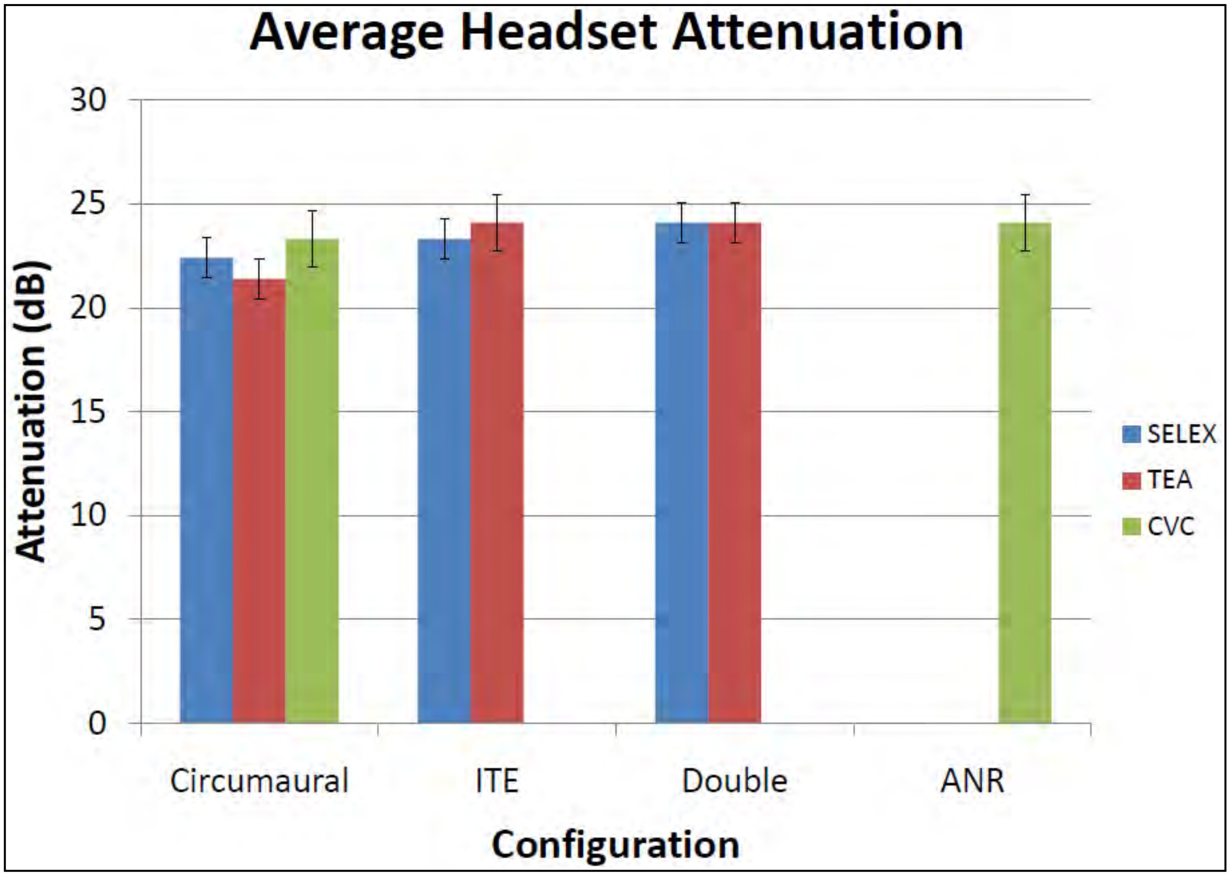

Figure 6. Average attenuation measured for each of the headsets. All measures are of passive attenuation, except for the CVC in the active noise reduction (ANR) configuration. Error bars refer to standard error.

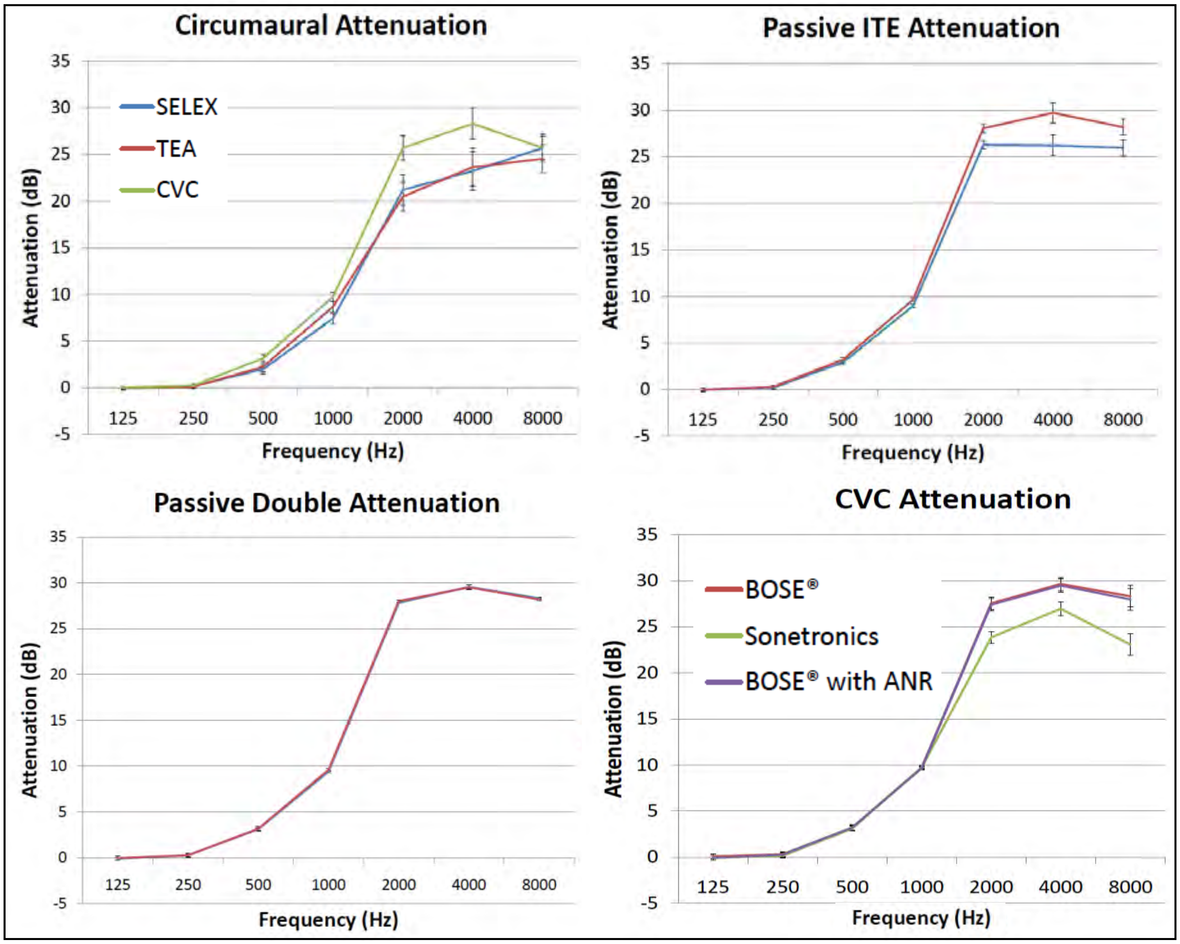

Figure 7. The first three panels show headset attenuation as measured for each octave band from 125 to 8000 Hz for each of the headset configurations. The fourth panel shows the attenuation measured for each of the CVC headsets separately and for the Bose headset with the ANR turned on. Error bars refer to standard error. All values shown are for passive attenuation, except for the Bose® CVC headset in the ANR configuration.

It is unclear why the Sonetronics headset measured as providing less attenuation than the Bose headset. It is possible that the fit of the Sonetronics headset was slightly different, perhaps because there was no top strap for adjustment, as there was for the Bose headset. The headset appeared to pull away from the earplates. Only the Bose headset provided ANR. In our measurements of the Bose headset with the ANR turned on, the ANR did not provide much additional protection at any frequency. This is somewhat puzzling, as ANR would be expected to provide about 5–10 dB of attenuation in the lower frequency ranges (below 500 Hz).

Using the G.R.A.S. 45CA fixture, measurements were made for two exemplars of each headset. An inspection of the standard deviations for this data set suggests that the variability within measurements of the same headset were the same as variability across different headsets, suggesting that most differences were due to variations in fitting. These values were similar for both sets of measurement (KEMAR and G.R.A.S. 45CA), suggesting that the headsets were all

pretty similar to each other and that using a subset of headsets is likely sufficient for providing an estimate of performance.

The spectral shape of the attenuation measured for the ITE and the dual protection conditions was similar to that observed with the KEMAR manikin. The seal of the circumaural muffs appeared to be much better with the G.R.A.S. 45CA fixture and that, in all cases, the amount of attenuation was greater, suggesting that there was some resonance occurring in the KEMAR manikin reducing the amount of attenuation measured.

Comparison of the Headsets

No significant differences were observed in any of the conditions. There were small differences in variability, similar to that observed for the KEMAR measurements. Specifically, the standard deviation for the TEA ITE configuration (0.5 dB) was lower than for the SELEX ITE configuration (1.8 dB). There was no difference in variability for the other two configurations: circumaural standard deviation was approximately 4.5 dB and the standard deviation for double protection was 0.5 dB. As before, the least variability was observed in the double hearing protection configuration.

Comparison of Configurations

ITE headsets provided more protection than the circumaural headset. This difference was significant for the KEMAR measurements $F(2,117) = 47.1$, $p < 0.001$. There was no statistically significant difference between wearing ITE or double hearing protection. However, the protection offered by double hearing protection was slightly less variable.

Talk-through Measurements

Measurements were made with the TEA and the SELEX circumaural headsets with the talk-thru feature turned on in order to quantify the level of noise passed through the headset in this mode. Two measurements were made: one with constant and a high noise level, and one with noise ramped up from non-hazardous to high levels.

The high-noise measurement used 103 dB A-wtd white noise. The talk-through modes were set at each of their amplification levels. As these headsets can function as “combat hearing aids” for Soldiers with hearing loss, it is important to understand that at times amplification above “safe” levels is desirable.

The second measurement was made with the noise initially set at about 78 dB A-wtd and then ramped up to 133 dB A-wtd. These measurements were intended to determine when the talk-through is shut off and the maximum level that reaches the ears.

Figure 8 gives the resulting levels for these measurements. They are provided for general information only and no statistical analysis was completed.

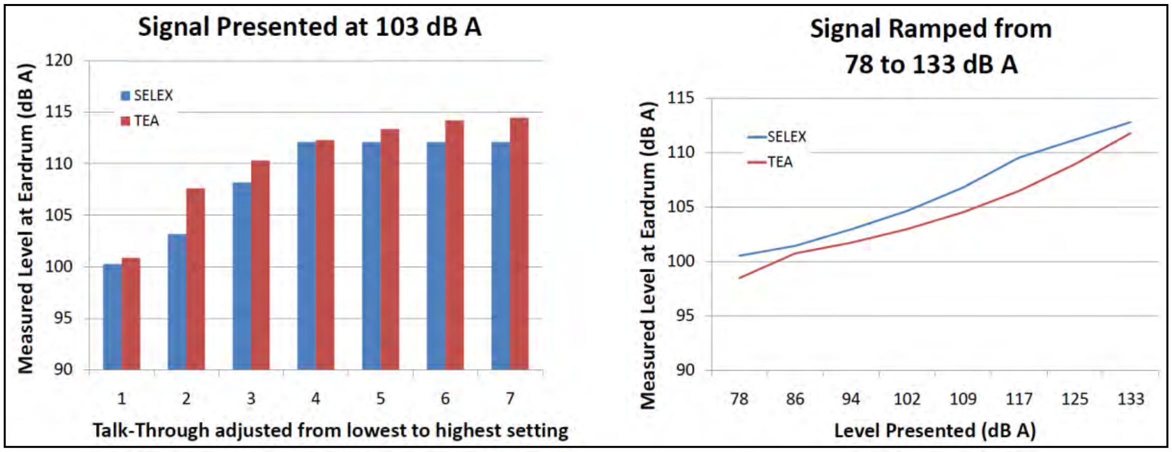

Figure 8. Measurements made with the talk-thru turned on: (left) The signal was presented at 103 dB A-wtd and continuous recordings were made while the level setting on the headset was successively increased from the lowest to the highest setting, and (right) the signal was presented at 78 dB A-wtd and a continuous recording was made while the sound level of the noise was increased to 133 dB A-wtd.

The MSA Sordin Supreme Pro advertises[†††] that the sound under the headset is limited to 82 dB A-wtd. It is presumed that this statement refers to the level of sound transmitted by the talk-through microphones; the actual noise level measured at the ears will depend on the overall level of noise in the environment and the passive attenuation of the headset. However, the levels we measured were considerably more than 82. The upper level measured here (approximately 115 dB A-wtd) is probably the upper level of the noise (133 dB A-wtd) minus the passive attenuation of the headset (about 18 dB)—meaning that the talk-through feature is probably not transmitting sound. However, when sound was presented at 78 dB A-wtd, the level measured under the headsets (set to the middle volume setting) was approximately 95–100 dB A-wtd. Thus, the headset was still amplifying sounds well above 82 dB. This may be an artifact of the mechanism used to trigger the shut-off. This trigger may use the rise time of the sound level, rather than the overall level. The expected shut-off trigger is likely impulsive noise, which has a near-instantaneous rise time to peak level. The noise presented was a broadband continuous noise. Normally, the wearer would turn off the talk-through feature when riding in a vehicle or near a generator (two common sources of this kind of noise). In future measurements, the cut-off trigger mechanism should be tested using both continuous and impulsive noise sources.

Given the imperative to be able to communicate in adverse noise environments—and the reasonable probability that many of the users of these headsets have experienced acoustic trauma—amplification is not necessarily a negative feature. Occasional speech, even amplified well above instantaneous levels of 82 dB, is not likely to exceed safe time-weighted-average levels. The published limits for noise exposure state that exposure must not exceed a time weighted average of 85 dB over an 8-h period. Speech consists of brief impulsive peaks and is

[†††] This was taken from the features displayed on a third party retailer of military headsets. http://www.srstactical.com/communications/supreme-range-headsets/msa-sordin-supreme-pro-iv/75302.html (last accessed on August 2, 2011).

generally not continuous, and therefore, unlikely to reach this average over time. However, Soldiers should be made aware that these headsets do not protect against dangerous levels of steady-state noise if the talk-through feature is turned on. They should be encouraged to turn off the talk-through feature when in a vehicle or otherwise in the presence of high steady-state noise. We suspect that a headset with less amplification would be less well received. Although ANR did not add significantly to the protection given by the Bose PICVC, ANR typically can be advantageous in reducing exposure to steady-state noise and may be a desirable feature in future designs.

4. Summary and Conclusions

There are no significant differences in the amount of the hearing protection provided by the two headsets under evaluation. Both provide adequate levels of protection comparable to the often-used Peltor headsets. The CVC, designed for use in mounted operations where the Soldier is buttoned down and not required to have ambient auditory situational awareness, is considered to provide superior levels of hearing protection. The attenuation measured for the ITE configurations of these headsets was only a few decibels less than that measured for the CVC. Since the headsets under test are not intended for mounted use, this level of protection is likely adequate for most situations. The amount of attenuation measured for the dual configuration was similar to that of the ITE configuration, but less variable.

The levels of sound under the headset exceed the advertised maximum of 82 dB A-wtd. If the transmitted sounds were speech, and not continuous, they would probably not, over time, exceed time-weighted sound exposure limits. Further, in noisy conditions, speech communication is of high value and amplification is needed to prevent loss of situational awareness. However, the shut-off mechanisms did not prevent higher levels of steady-state noise. Users should be advised to turn off the talk-through microphones when exposed to steady-state noise.

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List of Symbols, Abbreviations, and Acronyms

ANR	active noise reduction
ANSI/ASA	American National Standards Institute/Acoustical Society of America
ARL	U.S. Army Research Laboratory
ATF	auditory test fixture
ATO	Army Technology Objective
CVC	Combat Vehicle Crewman
EPA	Environmental Protection Agency
EPLRS	Enhanced Position Location Reporting System
HEaDS-UP	Helmet Electronics and Display System-Upgradeable Protection
HPD	hearing protective device
HRED	Human Research and Engineering Directorate
ITE	in-the-ear
KEMAR	Knowles Electronic Manikin for Acoustic Research
MIRE	Microphone in Real Ear
MSA	Mine Safety Appliances
NIOSH	National Institute for Occupational Safety and Health
NRR	Noise Reduction Rating
NSRDEC	Natick Soldier Research, Development, and Engineering Center
PICVC	Product Improved CVC
PTT	push-to-talk
REAT	Real-ear Attenuation at Threshold
SELEX	SELEX Communications
TCAPS	tactical communication and protection systems

TEA	Television Equipment Associates
WSRT	Wearable Soldier Radio Terminal

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